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OVIPOSITION PREFERENCES OF *SCIRTOTHRIPS PERSEAE* NAKAHARA (THYSANOPTERA: THRIPIDAE) IN SOUTHERN CALIFORNIA AVOCADO ORCHARDS

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Abstract.—A survey was conducted over the period July 1998–1999 to determine the oviposition preferences of female *Scirtothrips perseae* in a southern California avocado orchard. Female thrips oviposited into the undersides and topsides of immature avocado leaves, small fruit, and petioles from immature fruit. A significant oviposition hierarchy was determined with immature fruit being most preferred for oviposition followed by undersides of immature leaves, immature fruit petioles, and the topsides of immature leaves. Immature leaf petioles and stems were not used for oviposition. Of field collected fruit, small fruit 25–54 mm in length were most preferred for oviposition as fruit in this size range, on average, had the greatest mean numbers of *S. perseae* larvae emerging from them. The results of this work have important applications for the development of integrated pest management (IPM) programs using carefully timed natural enemy releases and pesticide applications to reduce low-density *S. perseae* populations before fruit of a size vulnerable to thrips feeding damage is set on trees.

Key Words.—Insecta *Scirtothrips perseae, Persea americana,* avocado, oviposition preference.

Scirtothrips perseae Nakahara (Thysanoptera: Thripidae) is a new pest of avocados (*Persea americana* Mill. [Lauraceae]) in California USA, and at time of discovery this insect was a species new to science (Nakahara 1997). Populations of *S. perseae* were first found in June 1996 damaging avocado fruit and foliage in Saticoy and Oxnard, Ventura County, and later around Irvine, Orange County, both in California. By July 1997, infestations of *S. perseae* were north of the initial discovery areas into San Luis Obispo County and south into San Diego County (Hoddle & Morse 1997). This pest is native to Mexico and Guatemala, and in California, *S. perseae* has only been found feeding on avocados suggesting that this thrips has a highly restricted host range (Hoddle et al. 2002).

Scirtothrips perseae builds to high densities on immature avocado foliage and cumulative feeding damage by larvae and adults can induce premature defoliation by mid to late spring. Thrips larvae and adults feeding on immature fruit are the primary cause of economic damage to avocados in California. Feeding damage results in brown scarring to fruit skin as it matures. Heavily infested orchards in Ventura County experienced 50–80% crop damage in 1997, and much of the damaged fruit was either unmarketable or downgraded in packinghouses. In 1998, crop loses due to damaged fruit that were downgraded and increased production costs due to insecticide use to control *S. perseae,* cost the California avocado industry approximately $7.6–13.4 million (US) (Hoddle et al. 1998, 1999).

Little is known about the developmental and reproductive biology, and field ecology of *S. perseae* in its native range or California. The purpose of this work was to determine what substrates are most preferred for oviposition by *S. perseae* in avocado orchards. Improved understanding of the egg-laying choices by females may assist in timing natural enemy releases or pesticide applications to protect the most preferred oviposition substrates. Optimizing treatment timing may maximize control impact and reduce the number of spray applications needed to prevent thrips from causing economic damage.

Materials and Methods

Study Site.—A commercial 40 ha 'Hass' avocado orchard (85% of fruit production in California is from the 'Hass' cultivar) in Bonsall, San Diego County, California, USA (33°16.45 N, 117°13.09 W, elevation 124 m) was selected for this study. This orchard had a very heavy *S. perseae* infestation when surveys were conducted over the period July 1998–July 1999. No sprays were applied for thrips control over this time period. The orchard was located in plant climate zone 2S (southern coastal valley [Kimball & Brooks 1959]) and subject to a moderating marine influence.

Surveying Potential Oviposition Sites.—Potential oviposition substrates used by *S. perseae* were investigated by collecting ¾ expanded avocado leaves, young green twigs from terminal branches, petioles from ¾ expanded leaves, immature fruit, and fruit petioles from the study site. Plant parts were measured, placed on foam pads saturated with water in stainless steel trays, and held in temperature cabinets at 25° C under long days (L:D 14:10). Glass cells (2.8 cm diameter, 1.5 cm height) with the top opening covered with polyester mesh (95 micron openings) were adhered to upper leaf and lower leaf surfaces with Duco® Stik-Tak (Devcon Consumer Product, Illinois, USA) to trap emerged larvae. Plant parts were examined daily, and numbers of emerged *S. perseae* larvae were recorded for seven consecutive days following field collection.

Emergence of Larvae from Immature Avocado Leaves.—Mean numbers of larvae emerging from immature leaves and percentage infested leaves were determined by making weekly collections of 20 leaves at the study site from July 1998–March 1999. Leaves were placed upper side down on water-saturated foam pads in stainless steel trays and held at 25° C under long days (L:D 14:10) in temperature controlled cabinets. Larval emergence per leaf was recorded daily for seven days.

Determining Avocado Fruit Size Preferences for Oviposition.—Substantial off bloom over the summer of 1998 supplemented normal fruit production in spring 1999 and resulted in significant numbers of fruit in all size categories being present over the course of this survey. Immature avocados were picked weekly from fruit bearing trees at the study site. A total of 1066 fruit were collected from 29 January 1999 to 12 July 1999. Harvested fruit were numbered, and per fruit lengths (mm) and diameters (mm) were recorded. Fruit were adhered to the bottoms of stainless steel pans with Duco® Stik-Tak, and pans were partially filled with water to prevent *S. perseae* larvae leaving fruit from which they had emerged. Fruit in pans were placed in temperature controlled cabinets at 25° C under long days (L:D 14:10) and numbers of emerged larvae per fruit were recorded and removed with a moistened paint brush daily for seven consecutive days. Fruit were placed in one of 15 size categories based on length. The mean number of emerged larvae, and percentage of fruit infested with *S. perseae* in each size category were calculated.

Statistical Analyses.—Numbers of *S. perseae* larvae emerging from potential oviposition substrates were compared using Log-likelihood Ratio Test (i.e., G-test) to determine if substrate preferences for oviposition existed. Pair-wise com-

Table 1. Total number of emerged *Scirtothrips perseae* larvae from potential oviposition substrates. Collected plant material was incubated at 25°C for seven days. Numbers followed by italicized Roman numerals are significantly different from each other.

Oviposition substrate	Size (cm) ± SE	n	No. emerged larvae
Young leaf petioles	5.95 ± 0.12[a]	40	0
¾ Expanded avocado leaves (tops)		52	4*i*
¾ Expanded avocado leaves (bottoms)		51	78*ii*
Thin green stems	0.75 ± 0.06[b]	40	0
Thick green stems	1.47 ± 0.10[b]	40	0
Immature fruit	2.85 ± 0.17[b]	15	43*iii*
Immature fruit petioles	9.90 ± 0.54[a]	15	5*iv*

[a] Mean length.
[b] Mean diameter.

parisons between substrates from which larvae emerged were made using χ^2 as sample sizes were large (Sokal and Rohlf 1995). Numbers of *S. perseae* larvae emerging per fruit in each size category were log-transformed and mean numbers of emerged larvae were compared across size categories using ANOVA in SAS (SAS 1990) with Tukey's Studentized Range Test at the 0.05 level of significance being used for means separation.

Results

Oviposition Preferences.—*Scirtothrips perseae* larvae emerged from the tops and bottoms of immature avocado leaves, immature fruit, and the petioles attached to collected fruit. Significant differences in larval emergence from different oviposition substrates were observed ($\chi_3^2 = 131.28$; $P < 0.001$). Significantly more *S. perseae* larvae emerged from immature fruit ($\chi_1^2 = 10.17$; $P = 0.001$) followed by emergence from the undersides of immature leaves ($\chi_1^2 = 17.25$; $P < 0.001$) > immature fruit petioles ($\chi_1^2 = 4.63$; $P = 0.031$) > topsides of immature leaves. Immature leaf petioles and stems were not used for oviposition (Table 1).

Larval Emergence Patterns from Immature Leaves.—Larval emergence from immature leaves declined to very low levels from August to mid November 1998. Emergence rates peaked at the end of February 1999 at 33.18 ± 10.05 emerged larvae (range 0–189 emerged larvae per leaf) per leaf and declined by approximately 50% to 15.58 ± 2.73 larvae per leaf in early April 1999 (Fig. 1A). During periods of very low larval thrips emergence, percentage of infested leaves reached zero on only four occasions, twice in September and November 1998 (Fig. 1B).

Fruit Size Preferences for Oviposition.—*Scirtothrips perseae* larvae emerged from 55.66% of 1066 fruit that were 4–96 mm in length. Significant differences in mean numbers of larvae emerging from each fruit size category ($F_{(14,1045)} = 45.75$; $P < 0.0005$) (Fig. 2A). The largest mean number (34.63 larvae per fruit ± 5.27 [SE]) of larvae per fruit emerged from fruit in the 40–44 mm length category and the lowest number of thrips larvae emerged from fruit >75 mm in length (0.05 larvae per fruit ± 0.04 [SE]) were observed (Fig. 2A). The highest percentage of infested fruit were 40–44 mm in length (94.37%) and the least infested fruit category (4.11%) were >75 mm in length (Fig. 2B).

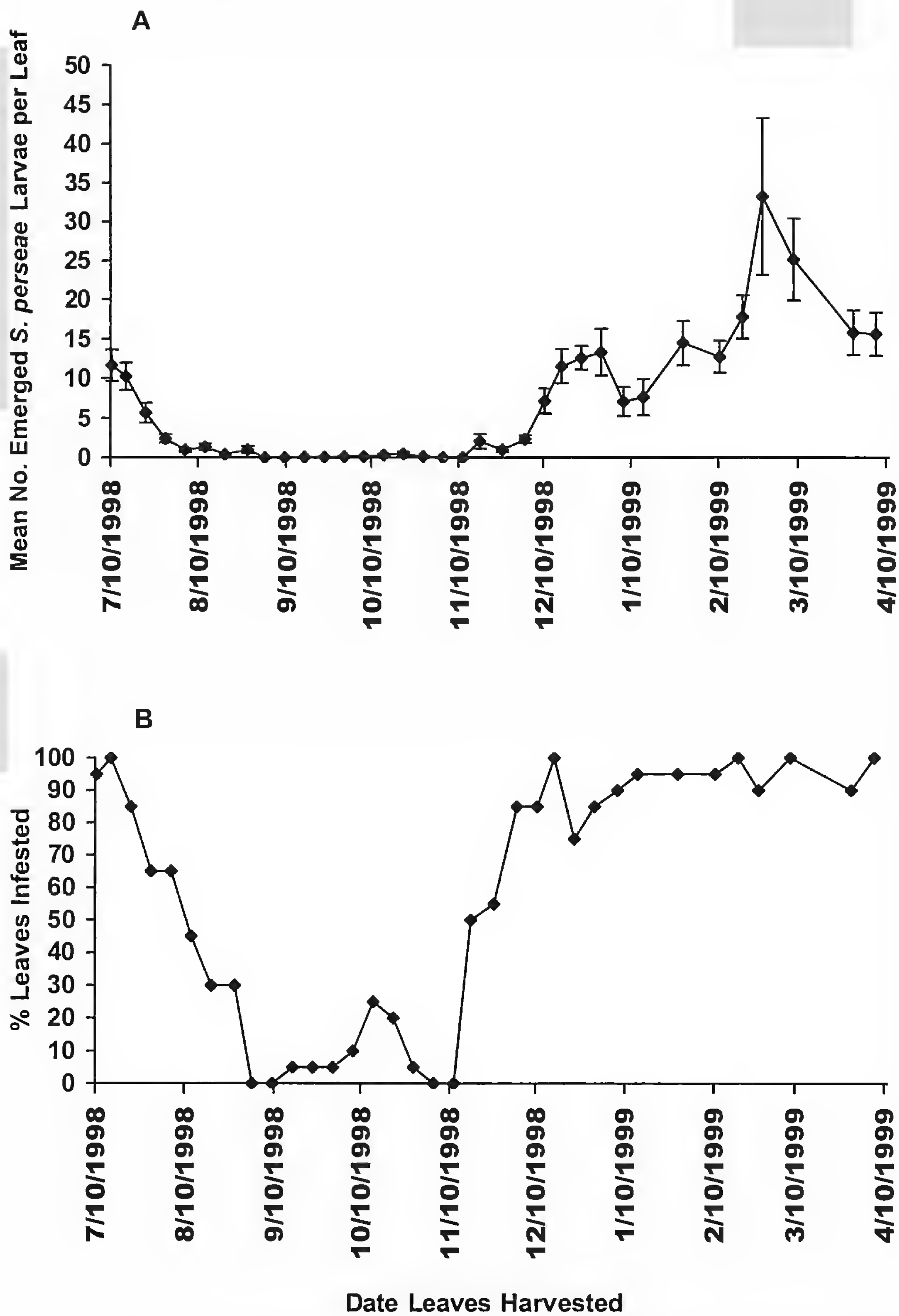

Figure 1. (A) Mean number (± SE) of emerged *Scirtothrips perseae* larvae per leaf and (B) percentage of leaves from which *S. perseae* larvae emerged for leaves collected at Bonsall, California.

Discussion

Scirtothrips perseae females preferentially oviposited into immature avocado fruit, with the undersides of immature avocado leaves being the next highly preferred oviposition site when these two substrates were simultaneously available. Upper surfaces of immature leaves and immature fruit petioles were the least favored oviposition substrates and no larvae were recovered from immature leaf

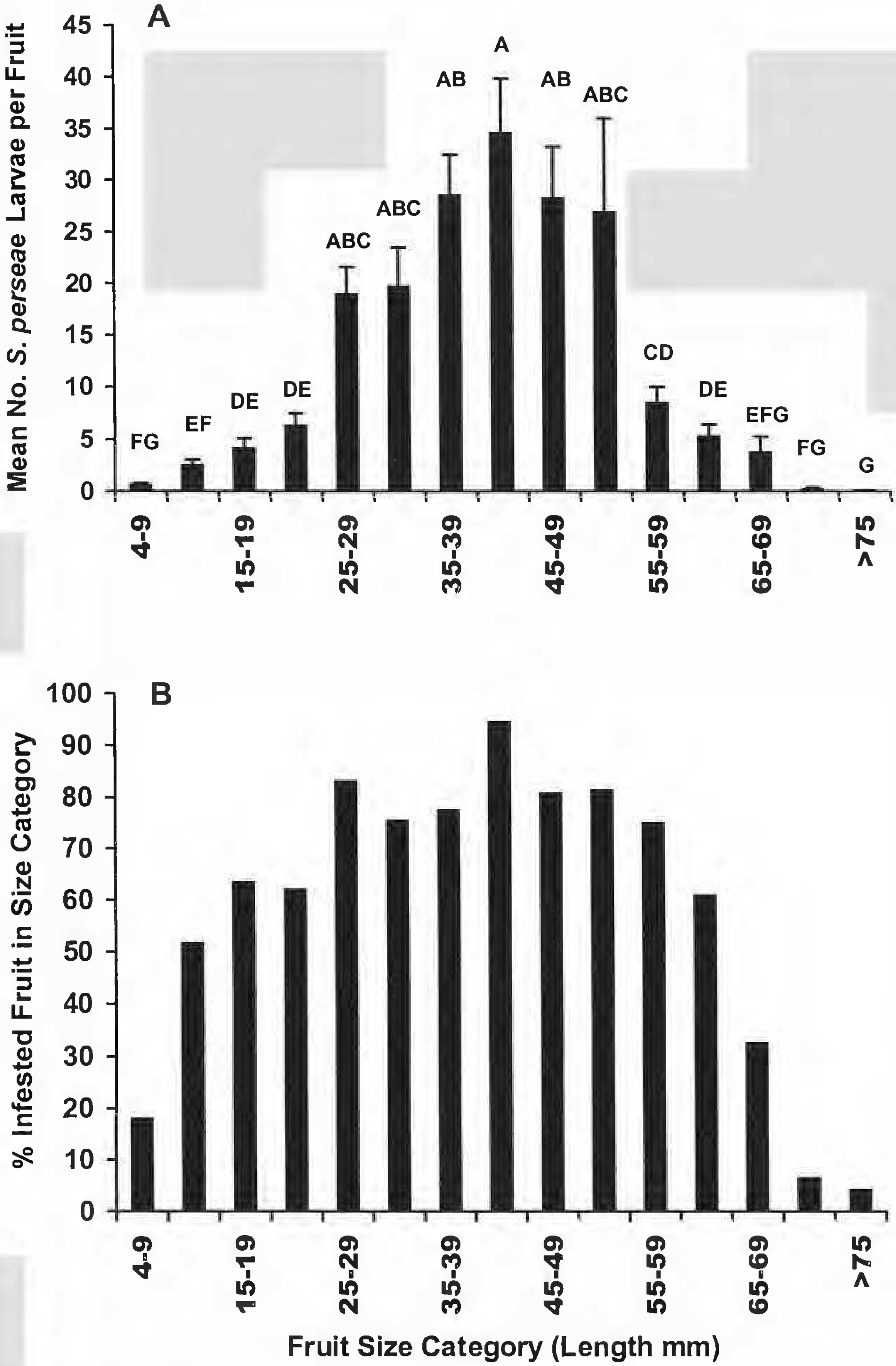

Figure 2. (A) Mean number (± SE) of emerged *Scirtothrips perseae* larvae per fruit length category, and (B) percentage of fruit in each length category from which *S. perseae* larvae emerged.

petioles and green twigs indicating that egg-laying females do not utilize these structures.

Significantly more *S. perseae* larvae emerged from field-collected fruit 25–54 mm in length than other size categories. Avocados spontaneously abort ~90% of fruit <10 mm in length (Yee et al. 2001a) and selection of fruit by female *S. perseae* in the size range 25–54 mm is probably under strong selection pressure as the feeding resource selected for larvae by females needs to be mature enough to remain on trees, yet tender enough to permit oviposition and sufficient larval feeding time for immature thrips to complete development before fruit skin is too thick to feed on (i.e., fruit >55 mm in length). Field observations indicate that *S. perseae* is most commonly found on fruit 20–40 mm in length, and most economic scarring occurs over a two week period when fruit 5–14 mm retained by trees are used for feeding by adult and immature thrips (Yee et al. 2001ab).

Emergence of *S. perseae* larvae from field collected leaves over July–August and November–March suggests that large founding populations of thrips could be accidentally imported into the USA on smuggled plant material. Work on *Sericothrips staphylinus* Haliday (Thysanoptera: Thripidae) used for the biological control of *Ulex europaeus* (L.), a noxious weed in New Zealand, has demonstrated that 33% of carefully managed releases of just 10 adult thrips into a permissive environment can result in establishment and proliferation (Memmott et al. 1998). On average, more than 10 larval *S. perseae* per leaf emerged over October-March in this study suggesting that individual leaves may harbor enough thrips eggs to found incipient populations.

As part of an IPM program being developed for *S. perseae* in California, monitoring of low-density pest populations and application of carefully timed insecticide sprays with high selectivity towards thrips on immature foliage during the pre-bloom period is being investigated. The results of this oviposition preference study suggest that proactive pesticide applications or natural enemy releases (e.g., *Franklinothrips orizabensis* Johansen [Thysanoptera: Aeolothripidae] [Hoddle et al. 2000, 2001a, b]) on trees with immature leaves in spring prior to fruit set may help to selectively protect the most preferred oviposition and larval feeding sites from *S. perseae.*

Acknowledgments

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